The Vital Role of Wireless Sensors Networks in Potential Applications

Amal H. Al-Gamdi[1] & Ibrahiem M. M. El Emary[2]
[1]Electronic Health Dept., Public Health Administration, Ministry Of Health
[2]Information Science Department, King Abdulaziz University
Jeddah, Saudi Arabia

Abstract

As mentioned by MIT's Technology review, Wireless Sensor Networks (WSNs) represent one of the top ten emerging technologies for the 21st century, so much research work has been done to promote the progress, including the various WSN topologies, congestion control of nodes, routing protocols, power consumption, location mechanism and time synchronization, etc. Also, it is agreed among researchers in the field of Communications and Information Technology that Wireless sensors networks play a vital role in many everyday applications such as agriculture, medicine, environment, military, industry and communications. So, this article shed the light on the latest and more recent findings of the researchers in this field. Achieving this goal implies us to review many of the applications that rely on wireless sensors explaining how this WSN perform the required functions properly well with high efficiency based on adopting new soft computing techniques..

Keywords: WSN, Automobile, healthcare, ad hoc, Routing, Congestion and architecture.

1. Introduction

The wireless sensor network is some type of an ad hoc network. Mainly it consists of small light weighted wireless nodes called sensor nodes, deployed in physical or environmental condition. It measure the physical parameters such as sound, pressure, temperature, and humidity. These sensor nodes deployed in large or thousand numbers and collaborate to form an ad hoc network capable of reporting to data collection sink (base station) [1]. Mainly a wireless sensor network (WSN) consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants and to cooperatively pass their data through the network to a main location. The more modern networks are bi-directional, also enabling control of sensor activity. Today such networks are used in many industrial and consumer applications, such as industrial process monitoring and control, machine health monitoring, and so on [2].

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The use of wireless sensor networks is increasing day by day and at the same time it faces the problem of energy constraints in terms of limited battery lifetime. As each node depends on energy for its activities, this has become a major issue in wireless sensor networks. The failure of one node can interrupt the entire system or application. Every
sensing node can be in active (for receiving and transmission activities), idle and sleep modes. In active mode nodes consume energy when receiving or transmitting data. In idle mode, the nodes consume almost the same amount of energy as in active mode, while in sleep mode, the nodes shutdown the radio to save the energy.
Recent advances in wireless communications, micro electro mechanical systems, and highly integrated electronics have enabled the implementation of very low cost, ultra-low power consumption, multifunctional sensors and actuators. The deployment of large numbers of these sensors and actuators has resulted in the development of wireless sensor networks . Unique characteristics such as a sensor-rich environment, flexibility, high fidelity, self-organization, rapid deployment, and inherent intelligent capability make WSNs the ideal structure for low cost energy usage evaluation, which is important to industrial plant managers in making planning decisions [3].
Today, wireless sensor networks are widely used in the commercial and industrial areas such as for e.g. environmental monitoring, habitat monitoring, healthcare, process monitoring and surveillance. For example, in a military area, we can use wireless sensor networks to monitor an activity. If an event is triggered, these sensor nodes sense it and send the information to the base station (called sink) by communicating with other nodes [4]. The various WSN applications require reliable network for collecting all data without loss from nodes. But on the other hand the inexpensive sensor nodes may not be highly reliable since they are limited in energy, memory space and processing capabilities, and the onboard sensors have direct contact with the environment. This results in error introduced in some of the sensor measurements while sensing, processing or reporting the data to the sink.
So in order to improve data integrity and detection reliability [5] The faulty sensor data have to be detected and filtered out while data without fault are aggregated and sent. Even when the object or event is reliably detected, error may be introduced in mutihop communication due to poor link quality and to improve the network based reliability can be by suitable routing protocol. Also even if the de- vices and links are working properly, sometimes the event or targets may not get detected due to limited coverage and connectivity and inefficient placement of sensor nodes.

2. Wireless Sensor Network Architecture

Wireless Sensor Network (WSN) is a network of large numbers – up to thousands – of tiny spatially distributed radio-equipped sensors. Each node in a sensor network is composed of a radio-transducer, a small microcontroller and a long lasting battery for energy source [6] . These sensor networks are used for gathering information needed by smart environments and are particularly useful in unattended situations where terrain, climate and other environmental constraints may hinder in the deployment of wired/conventional networks. An individual node failure is not an issue because of the

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large scale deployment of these nodes and normally the target area is monitored by several nodes. Primarily these sensors are used for data acquisition and are required to disseminate the acquired parameters to special nodes called sinks or base-stations over the wireless link as shown in Fig.1. The base-station or sink collects data from all the nodes, and then analyzes this data to draw conclusions about the on-going activity in the area of interest. Sinks or base- stations being powerful data processors can act as gateways to other existing communications infrastructure or to the Internet where a user can have access to the reported data.

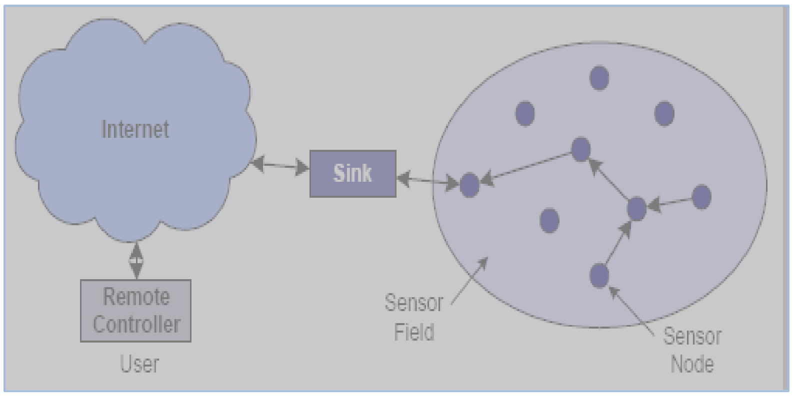

Fig. 1. Sensor Network Architecture [6]

A wireless sensor network (WSN) consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants and to cooperatively pass their data through the network to a main location. The more modern networks are bi-directional, also enabling control of sensor activity. Today such networks are used in many industrial and consumer applications, such as industrial process monitoring and control, machine health monitoring, and so on. Typically, a sensor node is a tiny device that includes three basic components: a sensing subsystem for data acquisition from the physical surrounding environment, a processing subsystem for local data processing and storage, and a wireless communication subsystem for data transmission. In addition, a power source supplies the energy needed by the device to perform the programmed task [2].
This power source often consists of a battery with a limited energy budget. There are different Sensors such as pressure, accelerometer, camera, thermal, microphone, etc. They monitor conditions at different locations, such as temperature, humidity, vehicular movement, lightning condition, pressure, soil makeup, noise levels, the presence or absence of certain kinds of objects, mechanical stress levels on attached objects, the current characteristics such as speed, direction and size of an object. Normally a sensor node combines the abilities to compute, communicate and sense.

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3. Various Challenges Facing WSN

Deployment of WSN face a number of great challenges that urge researches to focus on it in order to reach an optimal performance of WSN [7]. below are some general challenges that have been faced in different WSNs applications · Hardware constraint: Since WSNs depend on battery based power devices; power supplier is the most important art in the sensor nodes. The less energy consumption devices in WSN are the most efficient and lasting WSN. The characteristic of sensor nodes; such as the computational capabilities and storage capacity; will also affect the performance and life time of WSN as they may increase the energy consumption and data redundancy. The size, processing, cost and the amount of the sensors in the applied environment should be taken in consideration while we develop WSNs.

- ***Power consumption:*** The limitation of power resources in WSNs vice versa the high energy consumption direct the researchers attentions to power conservation and power management approaches that will effectively prolong the WSN lifetime.
- ***Deployment:*** A WSN is an infrastructure less randomly deployed network consist of small autonomously distributed sensors. The network deployment can be densely by a huge number of sensors in applied area of application or sparse network with few and limited number of sensors. Communication in WSNs is achieved by single or multi number of hops between sensors. The importance of application as well as the cost of deployment controls the class of WSN deployment.
- ***Scalability:*** WSNs should be able to support variety of routing protocols, huge nodes number and wide area of application as well as the frequent increases of network expansion. The scale of performance and workload of WSN should not be anticipated during the initial network design stage.
- ***Flexibility:*** Due to the wide diverse of WSN application, as well as the network constraints and scarcity of resources, some sort of flexibility are needed such as different network deployment schemes and topologies, routing protocols, power management methods and so on.
- ***Reliability:*** A WSN should be able to adapt and manage the corruption of the network in case of node failure. The functionality and performance to WSNs should not be affected negatively. Some fault tolerance techniques ensure reliability in WSNs.
- ***Connectivity:*** Maintain connectivity among all sensor nodes through the network life time is a very challenging issue. The importance of each sensor node as well as the importance of sensed data and routing route that each sensor may take urges the network to preserve the life of each node. Some sleep modes can be practiced by some nodes in order to reduce the rate of harvested energy.
- ***Lifetime:*** The longevity and coverage of the WSN should be guaranteed. The main emphasis is to prolong the network lifetime. Sensor nodes are finite life time devices as they are battery powered. Some adapting mechanisms such as power management techniques and adaptive routing protocols are used to

overcome the limited resources efficiently and to ensure the maximum network lifetime.

4. Approaches Used to Improve the Performance of WSN

The efficient utilization of energy in WSN is a bottleneck problem that affects the performance and the life time of network [5]. Energy consumption attentiveness and power management approaches are recently addressed by researches to tackle this problem. Optimal routing technique and energy optimization usage are significantly affecting the WSNs performance and guarantee the extension of the network life time. Due to WSNs constraints and especially the sensors` energy scarcity, a smart routing should be done to balance the energy consumption among nodes, therefore prolonging the network lifetime and insuring network coverage. Deploying smart and intellectual techniques enhances the effectiveness of wireless sensor network. Different soft computing paradigms have been studied and examined by researches to optimize WSN routing with the consideration of the power consumption, network challenges and design and deployment aspects. The soft computing paradigms such as Reinforcement Learning (RL), Swarm Intelligence (SI), Evolutionary Algorithms (EA), Fuzzy Logic (FL), Neural Networks (NN) and Artificial Immune System (AIS) have been applied. The important works achieved [8] for improving the WSN performance in view point of different direction given as follows:-

- **Firstly regarding the congestion control problem: [9]** proposed a cross-layer TDMA based protocol that guarantees collision-free communication by scheduling slots for each node and results in significant energy savings. This has the main challenge to determine the collision-free slots that are to be assigned to wireless nodes in a multiple-hop network. [5] proposed a novel upstream congestion control protocol for WSNs named Priority based Congestion Control Protocol, which introduced node priority index to reflect the importance of each sensor node. This utilizes a cross-layer optimization and imposes a hop-by-hop approach to control congestion. [6] presented a new Queue based Congestion Control Protocol with priority support, using the queue length as an indication of congestion degree. In this approach, the rate assignment to each traffic source is based on its priority index as well as its current congestion degree. [5] proposed a node priority-based congestion control protocol for wireless sensor networks. In this, the node priority index is introduced to reflect the importance of each node and uses packet inter-arrival time along with packet service time to measure a parameter defined as congestion degree and imposes hop-by-hop control based measurement as well as node priority index.

- **Secondly regarding the avoidance of routing problems:** The limited energy supply of sensor nodes necessitates energy-awareness at most layers of networking protocol stack including the network layer. In addition, many applications of sensor networks require the deployment of a large number of sensor nodes making it impractical to build a global addressing scheme. Moreover, in contrary to contemporary communication networks almost all applications of sensor networks require the flow of sensed data from multiple sources to a particular sink. These unique characteristics of sensor networks have made efficient routing of sensor data one of the technical challenges in wireless sensor networks . While a number of routing protocols pursued a data centric methodology by naming the data, some considered clustering the sensor nodes in order to decrease the number of transmitted messages to the sink node and have a more scalable setup. Other protocols either adopted a location-based routes setup or strived to achieve energy saving through activation of a limited subset of nodes. In addition, with the increasing interest in the applications that require certain end-to-end performance guarantees, a few routing protocols have been proposed for providing energy efficient relaying of delay-constrained data . While the goals of most published techniques are increasing network lifetime and on-time delivery of data through clever architecture and management of the network, none of the work considered the possibility of relocating the sink (gateway) node for enhanced network performance.

- **Thirdly regarding the problem of power saving:** Ideally, we would like the sensor network to perform its functionality as long as possible. Optimal routing in energy constrained networks is not practically feasible (because it requires future knowledge). However, we can soften our requirements towards a statistically optimal scheme, which maximizes the network functionality considered over all possible future activity. A scheme is energy efficient (in contrast to „energy optimal") when it is statistically optimal and causal (i.e. takes only past and present into account). In most practical surveillance or monitoring applications, we do not want any coverage gaps to develop. We therefore define the lifetime we want to maximize as the worst case time until a node breaks down, instead of the average time over all scenarios. However, taking into account all possible future scenarios is too computationally intensive, even for simulations. It is therefore certainly unworkable as a guideline to base practical schemes on. Many routing and data transfer protocols have been specifically designed for WSNs [11]. Most sensor network routing protocols are, however, quite simple and for this reason are sometimes insecure.

5. Potential Applications of Wireless Sensor Networks

Sensor networks may consist of many different types of sensors such as seismic, low sampling rate magnetic, thermal, visual, infrared, acoustic and radar, which are able to monitor a wide variety of ambient conditions that include the following [12]: Humidity, Temperature. Vehicular movement, Lightning condition, Pressure, Soil makeup, Noise levels, The presence or absence of certain kinds of objects, Mechanical stress levels on

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attached objects, and The current characteristics such as speed, direction, and size of an object.
Sensor nodes can be used for continuous sensing, event detection, event ID, location sensing, and local control of actuators. The concept of micro-sensing and wireless connection of these nodes promise many new application areas. We categorize the applications into military, environment, health, home and other commercial areas. It is possible to expand this classification with more categories such as space exploration, chemical processing and disaster relief. Below a more details of these applications are given as follows:-

5.1. WSN in Medical Applications

Coming along with the urgent development of wireless technology, wireless devices have invaded the medical area with a wide range of capability. Not only improving the quality of life of patients and doctor-patient efficiency, wireless technology enables clinicians to monitor patients remotely and give them timely health information, reminders, and support – potentially extending the reach of health care by making it available anywhere, anytime.
Some of the health applications for sensor networks are providing interfaces for the disabled [12]; integrated patient monitoring; diagnostics; drug administration in hospitals; monitoring the movements and internal processes of insects or other small animals; telemonitoring of human physiological data; and tracking and monitoring doctors and patients inside a hospital.
Telemonitoring of human physiological data: The physiological data collected by the sensor networks can be stored for a long period of time , and can be used for medical exploration . The installed sensor networks can also monitor and detect elderly people's behavior, e.g., a fall. These small sensor nodes allow the subject a greater freedom of movement and allow doctors to identify pre-defined symptoms earlier [56]. Also, they facilitate a higher quality of life for the subjects compared to the treatment centers. A ''Health Smart Home'' is designed in the Faculty of Medicine in Grenoble—France to validate the feasibility of such system.
Tracking and monitoring doctors and patients inside a hospital: Each patient has small and light weight sensor nodes attached to them. Each sensor node has its specific task. For example, one sensor node may be detecting the heart rate while another is detecting the blood pressure. Doctors may also carry a sensor node, which allows other doctors to locate them within the hospital. Drug administration in hospitals: If sensor nodes can be attached to medications, the chance of getting and prescribing the wrong medication to patients can be minimized. Because, patients will have sensor nodes that identify their allergies and required medications. Computerized systems as described in [12] have shown that they can help minimize adverse drug events.

5.2. Environmental Monitoring

The capability of sensing temperature, light, status of frames (windows, doors), air streams and indoor air pollution can be utilized for optimal control of the indoor

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environment. Moreover, a major waste of energy occurs through unnecessary heating or cooling of buildings. Motes can help in using heaters, fans and other relevant equipment at a reasonable and economic way, leading to a healthier environment and greater level of comfort for residents. The use of motes to improve the environmental conditions inside buildings has also preoccupied the American Society of Heating, Refrigerating and Air- Conditioning Engineers (ASHRAE). A wireless network was deployed in an office building at Pacific Northwest National Laboratory, Richland, Washington, to survey the advantages and drawbacks of wireless technology in operation of heating, ventilation and air condition (HVAC) systems. .

Applications can be mitigation of fire and earthquake damages as it is envisioned in [8]. Fire and smoke detection is something common, nowadays, in buildings and in most countries it is imposed by relevant laws. The existence, also, of light-signals indicating exits is, usually, obligatory in big buildings. However, these two systems do not cooperate in case of a fire. The installation of sensor networks in buildings can lead to the integration of these two systems. So, the role of a sensor network is to guide the trapped residents through the safest route and save their lives.

5.3. Planning and Industry Application

Electric energy systems can also benefit from deploying motes to households and, generally, to consumers of electric power [3]. Such a scheme is being investigated in CITRIS . “Electric economy” always deals with maximum values of electricity consumption. This value has to be kept as low as possible for economic reasons relevant to production. Peaks in electricity demand can be diminished by attaching wireless sensors as components of smart appliances. In a program envisioned by CITRIS, Smart Energy Distribution and Consumption is deployed in three stages. First, the end user monitors their appliances and finds out defective or energy exorbitant-consumers. Next, feedback is employed between end user and supplier (real-time pricing). Finally, measuring of environmental parameters slips into the system operation. In this phase the indoor environmental monitoring application described earlier is encountered.

Intel is also conducting research in this area. The point of view for Intel is mobile robots that act as gateways into wireless sensor networks. Actions that aim to serve and support the operation of a sensor network are described in [12]. Examples of tasks are: sustaining the energy resources of the sensor network indefinitely, maintaining and configuring hardware, detecting sensor failures and appropriate deployment for connectivity among nodes. Another relevant work [12] concerns localization of nodes in a sensor network by means of mobile robots. This approach tries to solve the problem of unifying a network that is separated because of disconnected groups of sensors (clusters). Of course, in all these cases robots are integrated parts of the sensor network. Energy evaluation and planning are important in industry for overall energy savings. Traditionally these functions are realized in wired systems formed by communication cables

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and various types of sensors. However, the installation and maintenance of these cables and sensors is usually much more expensive than the cost of the sensors themselves. Recent advances in wireless communications, micro-electro-mechanical systems, and highly integrated electronics allowed the introduction of wireless sensor networks (WSN). WSNs have unique functional characteristics that enables low cost energy evaluation and planning in industrial plants. This paper proposes a closed loop energy evaluation and planning system with the WSN architecture. The importance of the proposed scheme lies in its non-intrusive, intelligent, and low cost nature. As the focus of this paper, the properties and architecture of the WSN in this application are discussed in detail. The applicability of the proposed system is analyzed and potential challenges are addressed. Finally, a demo system is constructed and experimental results are presented.

5.4. Automobile Application

The application of wireless sensor networks to the automobile constitutes a challenge to be faced in this end devour; we conceived a wireless sensor system capable to collect, process and supply several types of technical information (to the user) during an automobile journey [13]. The examples are acceleration and fuel consumption, identification of wrong tires pressure value, acknowledgment of illumination failures (turn lights, brake lights, front lights, and register plate lights), and determination of the vital signals of the driver. The conception of a WSN capable of measuring, processing and supplying diverse types of information to the user during an automobile journey. The examples are acceleration and fuel consumption, identification of incorrect tire pressure, failures of illumination, and evaluation of the vital signals of the driver. Beside a survey on the concepts, the wireless sensor network itself (transmitter/ receiver/control board) was configured, and aspects of the architecture and protocols were addressed. By using the calibration curves for the light and temperature sensors , precise experimental values were extracted. Security aspects were also identified, and the difficulties and solutions were discussed. Competition cars in a controlled environment constitute a suitable scenario for experimental work. Besides, the evolutions in this field promise a lot in the automobile industry, e.g., for cooperation among cars for road safety purposes.

6. Concluded Remarks

In the current time, there is a new era of ubiquitous computing . One type of such ubiquitous is wireless sensor technologies which is characterized with a great potential in opening a world of sensing applications. Wireless sensors and wireless sensor networks have come to the forefront of the scientific community recently. This is the consequence of engineering increasingly smaller sized devices, which enable many applications. In this paper, we made an attempt to summarize the major contributions of various

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researchers in the field WSN applications. In the same time, we have been touch the critical challenges that face WSN and try to put some solutions for such problems in order to get acceptable level of service.

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